STE Developer Addendum

The Atari **ST**^{E}

Compatible with ST, 1000s of software titles available.

New

- Extended color palette of 4096 colors, from 512
- Hardware support for horizontal and vertical scrolling
- Ready for external GENLOCK
- Stereo 8 bit PCM sound
- Light gun, paddle and new joystick ports.
- 256K ROM from 192K includes
  - Move as well as copy files
  - Rename folders
  - Autoboot GEM applications
  - New file selector
  - Faster desktop
  - Large palette support
  - Fast hard-disk support
  - Folder limitations lifted
  - Memory management improved
  - Keyboard reset

STE Developer Addendum

This addendum is a set of documents that allows the ST developer to use the new features of the STE. These new features are in the areas of graphics, sound and interface ports.

The STE has a palette of 4096 colors compared to the ST palette of 512 colors. Also the STE has hardware support for vertical and horizontal scrolling. Support has also been added for external GENLOCK.

Sound on the STE has the ST sound as well as 8 bit stereo DMA sound with variable playback frequencies.

The STE also has two new controller ports that allow for new joysticks as well as a light gun and paddle controllers.

Genlock and the STE

The ST (and STE) chip set have the ability to accept external sync. This is controlled by bit 0 at FF820A, as documented in the ST Hardware Specification. This was done to allow the synchronization of the ST video with an external source (a process usually known as GENLOCK). However, in order to do this reliably the system clock must also be phase-locked (or synchronized in some other way) to the input sync signals. No way to do this was provided in the ST, as a result the only GENLOCKs available are internal modifications (usually for the MEGA).

The STE allows this to be done without opening the case. To inject a system clock ground pin three (GPO) on the monitor connector and then inject the clock into pin 4 (mono detect). The internal frequency of this clock is 32.215905 MHz (NTSC) and 32.084988 MHz (PAL). Note: DO NOT SWITCH CLOCK SOURCE WHILE THE SYSTEM IS ACTIVE.

As a result of this GPO is no longer available.

Controllers

FF9200

Fire Buttons

FF9202

Joy 3 Joy 1 Joy 2 Joy 0

Joy sticks.
Four new joystick ports are added. These ports are controlled directly by the 68000. The current state may be sampled at any time by reading the above locations. Joystick 0 and Joystick 2 direction bits are read/write. If written to they will be driven until a read is performed. Similarly, they will not be driven after a read until a write is performed.

FF9210  (X Paddle 0)

FF9212  (Y Paddle 0)

FF9214  (X Paddle 1)

FF9216  (Y Paddle 1)

Paddles.
One pair of paddles can be plugged into Joystick 0 (Paddle 0). A second set can be plugged into Joystick 1 (Paddle 1). The current position of each of the four paddles is reported at these locations. The fire buttons are the same as for the respective joystick. The triggers for the paddles are read as bits one and two of FF9202 (JOY0 Left and Right)

FF9220  (X Position)

FF9222  (Y Position)

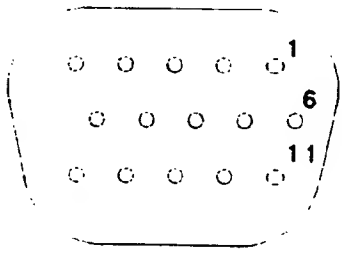
Light Gun / Pen.
A light gun or pen can be plugged into Joystick 0. The current position that the gun or pen is pointing to is reported by these registers. The position is accurate to within (X direction only):

4 Pixels in 320x200 Mode
8 Pixels in 640x200 Mode
16 Pixels in 640x400 Mode

Accurate to 1 pixel in the Y direction in all modes. Accuracies do not account for the quality of the light gun or pen. Note that the X position is given in pixels for 320x200 only. In order to get correct results in 640x200 mode this number needs to be shifted left one bit and in 640x400 mode this number needs to be shifted left two bits.

New Controller Pinout

This pinout is for ports 0 and 1. Ports 2/3 are on the other DB15 connector.



1	UP 0
2	DN 0
3	LT 0
4	RT 0
5	PAD 0Y
6	FIRE 0
7	VCC
8	NC
9	GND
10	FIRE 1
11	UP 1
12	DN 1
13	LT 1
14	RT 1
15	PAD 0X

Video Modifications

FF8204  (High)

FF8206 

FF8208  (Low)

Video Address Counter.
Now read/write. Allows update of the video refresh address during the frame. The effect is immediate, therefore it should be reloaded carefully (or during blanking) to provide reliable results.

FF820C 

Low byte of the video base address. This register completes the set on ST
Allows positioning screen on word boundaries and thus vertical scrolling.

FF820E 

Offset to next line.
Number of words from end of line to beginning of next line minus one. Allows virtual screen to be wider than physical screen. Acts like an ST when cleared. Cleared at reset.

FF8240 through FF825E 

Color Pallete.
A fourth bit of resolution is added to each color. Note that the least significant bit is added above the old most signilicant bit to remain compatible with the ST.

FF8264 

Horizontal Bit-wise Scroll.
Delays the start of screen by the specified number of bits.

How to Implement Fine Scrolling on the STE.

The purpose of this document is to describe how to use the capabilities of the STE to achieve bit-wise fine-scrolling and vertical split screens. Horizontal and vertical scrolling are discussed and an example program is provided. Split screen effects are discussed and an example program with multiple independent scrolling regions is provided.

Three new registers are provided to implement fine-scrolling and split screen displays:

1) HSCROLL - This register contains the pixel scroll offset. If it is zero, this is the same as an ordinary ST. If it is non-zero, it indicates which data bits constitute the first pixel from the first word of data. That is, the leftmost displayed pixel is selected from the first data word(s) of a given line by this register.

2) LINEWID - This register indicates the number of extra words of data (beyond that required by an ordinary ST at the same resolution) which represent a single display line. If it is zero, this is the same as an ordinary ST. If it is non-zero, that many additional words of data will constitute a single video line (thus allowing virtual screens wider than the displayed screen). *CAUTION*- In fact, this register contains the word offset which the display processor will add to the video display address to point to the next line. If you are actively scrolling (HSCROLL <> 0), this register should contain the additional width of a display line *minus one data fetch* (in low resolution one data fetch would be four words, one word for monochrome, etc.).

3) VBASELO - This register contains the low-order byte of the video display base address. It can be altered at any time and will affect the next display processor data fetch. It is recommended that the video display address be altered only during vertical and horizontal blanking or display garbage may result.

These registers, when used in combination, can provide several video effects. In this document we will discuss only fine-scrolling and split-screen displays.

Fine Scrolling:

Many games use horizontal and vertical scrolling techniques to provide virtual playfields which are larger than a single screen. We will first discuss vertical scrolling (line-wise), then horizontal scrolling (pixel-wise) and finally the example program "neowall.s" which combines both.

Vertical Scrolling:

To scroll line-wise, we simply alter the video display address by one line each time we wish to scroll one line. This is done at vertical blank interrupt time by writing to the three eight-bit video display address registers to define a twenty-four-bit pointer into memory. Naturally, additional data must be available to be displayed. We might imagine this as a tall, skinny screen which we are opening a window onto for the user. The video display address registers define where this window will start.

Horizontal Scrolling:

To scroll horizontally we might also adjust the video display address. If that was all we did, we would find that the screen would jump sideways in sixteen pixel increments. To achieve smooth pixel-wise scrolling we must use the HSCROLL register to select where within each sixteen pixel block we wish to start displaying data to the screen. Finally, we must adjust the LINEWID register to reflect both the fact that each line of video data is wider than a single display line and any display processor fetch incurred by a non-zero value of HSCROLL. All this is done at vertical blank interrupt time. Naturally, additional data must be available to be

displayed. We might imagine this as an extremely wide screen which we are opening a window onto for the user. These registers define where this window will start.

For Example:
The program "neowall.s" reads in nine NEOchrome™ picture files, organizes them into a three by three grid and allows the user to scroll both horizontally and vertically over the images. The heart of this program (the only interesting thing about it actually) is the vertical blank interrupt server. This routine first determines the pixel offset and loads it into HSCROLL. The LINEWID register is now set to indicate that each virtual line is three times longer than the actual display width. If we are actively scrolling, this amount is reduced to reflect the additional four-plane data fetch which will be caused by the scrolling. Finally, the video display address is computed to designate a window onto the grid of pictures. This twenty-four-bit address determines where the upper-left corner of the displayed region begins in memory. Thus, every frame an arbitrary portion of the total image is selected for display. The speed and resolution of this scrolling technique is limited only by the dexterity of the user.

Split Screen:
In many applications it is desirable to subdivide the screen into several independent regions. On the STE you may reload some video registers on a line-by-line basis (using horizontal blanking interrupts) to split the screen vertically into multiple independent regions. A single screen no longer need be a contiguous block of storage, but could be composed of dozens of strips which might reside in memory in any order. The same data could be repeated on one or more display lines. Individual regions might each have their own individual data and scrolling directions.

For Example:
The program "hscroll.s" reads in a NEOchrome™ picture file and duplicates each line of the image. This, combined with the proper use of LINEWID, effectively places two copies of the same picture side-by-side. Next, both vertical and horizontal blanking interrupt vectors are captured and the horizontal blanking interrupt is enabled in counter mode. To prevent flicker caused by keyboard input, the IKBD/MIDI interrupt priority is lowered below that of the HBL interrupt. Note that the program 'main loop' doesn't even call the BIOS to check the keyboard, since the BIOS sets the IPL up and causes flicker by locking out horizontal interrupts - this may cause trouble for programs in the real world. The screen is effectively divided into ten regions which scroll independently of one another. There are two ten-element arrays which contain the base address of each region and its current scroll offset. At vertical blank interrupt time we compute the final display values for each region in advance and store them into a third array. We then initialize the display processor for the first region and request an interrupt every twenty lines (actually every twenty horizontal blankings). During each horizontal interrupt service, we quickly reload the video display address registers and the HSCROLL register. This must be done immediately - before the display processor has time to start the current line or garbage may result. Note that horizontal blank interrupts are triggered by the display processor having finished reading the previous data line. You have approximately 144 machine cycles to reload the HSCROLL and video display registers before they will be used again by the display processor. Finally, the LINEWID register is set, this need only be done before the processor finishes reading the data for the current display line. We then pre-compute the data we will need for the next horizontal interrupt to shave few more cycles off the critical path and exit.

```
                                ;
                                ;       HSCROLL.S   Horizontal Scrolling Demo
                                ;       THE ONE LINE VERSION
                                ;
                                ;       Copyright 1988 ATARI CORP.
                                ;       Started 9/12/88 .. Rob Zdybel
                                ;


                                        .text
                                        .include atari
                                        .list


                                ;
                                ;       HARDWARE CONSTANTS
                                ;
FFFF820D                        vbaselo =       $ffff820d               ; Video Base Address (lo)
FFFF820F                        linewid =       $ffff820f               ; Width of a scan-line (Words, minus 1)
FFFF8265                        hscroll =       $ffff8265               ; Horizontal scroll count (0 .. 15)


                                ;
                                ;       SYSTEM CONSTANTS
                                ;
00000070                        vblvec  =       $70             ; System VBlank Vector
00000118                        ikbdvec =       $118            ; IKBD/MIDI (6850) Vector
00000120                        hblvec  =       $120            ; Horizontal Blank Counter (68901) Vector


                                ;
                                ;       LOCAL CONSTANTS
                                ;


                                ;
                                ;       System Initialization
                                ;
                                start:
00000000 2A4F                           move.l  a7,a5
00000002 2E7Cxxxxxxxx                   move.l  #mystack,a7     ; Get Our Own Local Stack
00000008 2A6D0004                       move.l  4(a5),a5        ; a5 = basepage address
0000000C 202D000C                       move.l  TEXTSZ(a5),d0
00000010 D0AD0014                       add.l   DATASZ(a5),d0
00000014 D0AD001C                       add.l   BSSSZ(a5),d0
00000018 D0BC00000100                   add.l   #$100,d0        ; RAM req'd = text+bss+data+BasePageLength
0000001E 2800                           move.l  d0,d4           ; d4 = RAM req'd
                                        Mshrink a5,d0           ; Return Excess Storage
00000020 2F00                 *         move.l  d0,-(sp)
00000022 2F0D                 *         move.l  a5,-(sp)
00000024 4267                 *         clr.w   -(sp)
                              *         Gemdos $4a,12
00000026 3F3C004A             *         move.w  #$4a,-(sp)
0000002A 4E41                 *         trap    #1
                              *         .if $c <= 8
                              -         addq    #$c,sp
                              -         .else
0000002C DEFC000C             *         add.w   #$c,sp
                              *         .endif

                                ;
                                ;       Other Initialization
                                ;
                                        Super                   ; enter supervisor mode
00000030 42A7                 *         clr.l   -(sp)
00000032 3F3C0020             *         move.w  #$20,-(sp)
00000036 4E41                 *         trap    #1
00000038 5C4F                 *         addq    #6,sp
0000003A 2F00                 *         move.l  d0,-(sp)        ; WARNING - Old SSP saved on stack.

                                        Fgetdta
                              *         Gemdos $2f,2
0000003C 3F3C002F             *         move.w  #$2f,-(sp)
00000040 4E41                 *         trap    #1
                              *         .if $2 <= 8
00000042 544F                 *         addq    #$2,sp
                              *         .else
                              -         add.w   #$2,sp
                              -         .endif
00000044 2848                           move.l  d0,a4
00000046 D8FC001E                       adda    #30,a4          ; a4 = Filename ptr
                                        Fsfirst #neofile,#0
0000004A 3F3C0000             *         move.w  #$0,-(sp)
0000004E 2F3Cxxxxxxxx         *         move.l  #neofile,-(sp)
                              *         Gemdos $4e,8
00000054 3F3C004E             *         move.w  #$4e,-(sp)
00000058 4E41                 *         trap    #1
                              *         .if $8 <= 8
0000005A 584F                 *         addq    #$8,sp
                              *         .else
                              -         add.w   #$8,sp
                              -         .endif
0000005C 4A40                           tst     d0
0000005E 6600xxxx                       bne     abort           ; IF (No NEO files) ABORT
                                        Fopen   a4,#0
00000062 3F3C0000             *         move.w  #$0,-(sp)
00000066 2F0C                 *         move.l  a4,-(sp)
```

```
                                *       Gemdos $3d,8
00000068  3F3C003D              *       move.w  #$3d,-(sp)
0000006C  4E41                  *       trap    #1
                                *       .if $8 <= 8
0000006E  584F                  *       addq    #$8,sp
                                *       .else
                                -       add.w   #$8,sp
54                              -       .endif
55  00000070  4A40                      tst     d0
56  00000072  6B00xxxx                  bmi     abort           ; IF (Error opening file) ABORT
57
58  00000076  33C0xxxxxxxx              move    d0,handle
                                        Fread   d0,#32128,#neobuff
0000007C  2F3Cxxxxxxxx          *       move.l  #neobuff,-(sp)
00000082  2F3C00007D00          *       move.l  #$7d00,-(sp)
00000088  3F00                  *       move.w  d0,-(sp)
                                *       Gemdos $3f,12
0000008A  3F3C003F              *       move.w  #$3f,-(sp)
0000008E  4E41                  *       trap    #1
                                *       .if $c <= 8
                                -       addq    #$c,sp
                                -       .else
00000090  DEFC000C              *       add.w   #$c,sp
59                              *       .endif
60  00000094  4A80                      tst.l   d0
61  00000096  6B00xxxx                  bmi     abort           ; IF (File Read Error) ABORT
                                        Fclose  handle
0000009A  3F39xxxxxxxx          *       move.w  handle,-(sp)
                                *       Gemdos $3e,4
000000A0  3F3C003E              *       move.w  #$3e,-(sp)
000000A4  4E41                  *       trap    #1
                                *       .if $4 <= 8
000000A6  584F                  *       addq    #$4,sp
                                *       .else
                                -       add.w   #$4,sp
62                              -       .endif
63  000000A8  4A40                      tst     d0
64  000000AA  6B00xxxx                  bmi     abort           ; IF (Error Closing a file) ABORT
65
66  000000AE  45F9xxxxxxxx              lea     neobuff+4,a2
67  000000B4  41F80240                  lea     palette,a0
68  000000B8  43F9xxxxxxxx              lea     oldpal,a1
69  000000BE  303C000F                  move    #15,d0
70  000000C2  3220              .ploop: move.w  (a0),(a1)+      ; save old color palette
71  000000C4  3480                      move.w  (a2)+,(a0)+     ; create new color palette
72  000000C6  51C8FFFA                  dbra    d0,.ploop
73
74  000000CA  303C00A0                  move    #160,d0         ; Double each display line
75  000000CE  41F9xxxxxxxx              lea     bigbuff,a0
76  000000D4  43F9xxxxxxxx              lea     neobuff+128,a1
77  000000DA  343C00C7                  move    #199,d2
78  000000DE  323C0027          .linlp: move    #39,d1          ; FOR (200 Lines) DO
79  000000E2  21180000          .dublp: move.l  (a1),(a0,d0)    ; duplicate line
80  000000E6  2089                      move.l  (a1)+,(a0)+
81  000000E8  51C9FFF8                  dbra    d1,.dublp
82  000000EC  D0C0                      adda    d0,a0
83  000000EE  51CAFFEE                  dbra    d2,.linlp
84
85  000000F2  41F9xxxxxxxx              lea     baseaddr,a0
86  000000F8  43F9xxxxxxxx              lea     xoffset,a1
87  000000FE  45F9xxxxxxxx              lea     bigbuff,a2
88  00000104  303C0009                  move    #9,d0
89  00000108  32FC0000          .strlp: move    #0,(a1)+        ; FOR (10 Strips) DO Init base and offset
90  0000010C  20CA                      move.l  a2,(a0)+
91  0000010E  D4FC1900                  adda    #320*20,a2
92  00000112  51C8FFF4                  dbra    d0,.strlp
93
94  00000116  23F80110xxxxxxxx          move.l  ikbdvec,oldikbd
95  0000011E  21FCxxxxxxxx0000          move.l  #ikbd,ikbdvec   ; IPL 5 hack for IKBD/MIDI
96
97  00000126  23F80070xxxxxxxx          move.l  vblvec,oldvbl
98  0000012E  21FCxxxxxxxx0000          move.l  #vbl,vblvec     ; Capture System VBlank Interrupt
99
100 00000136  21FCxxxxxxxx0000          move.l  #hbl,hblvec     ; Capture HBlank Interrupt
101 0000013E  08F800000FA13             bset.b  #0,imra
102 00000144  08F800000FA07             bset.b  #0,iera         ; Enable Hblank
103
104                             ;
105                             ;       Scrolling Demo loop
106                             ;
107                             mavelp:
                                        Bconstat CON            ; Keyboard Polling
0000014A  3F3C0002              *       move.w  #CON,-(sp)
                                *       Bios 1,4
0000014E  3F3C0001              *       move.w  #$1,-(sp)
00000152  4E4D                  *       trap    #13
                                *       .if $4 <= 8
00000154  584F                  *       addq    #$4,sp
                                *       .else
                                -       add.w   #$4,sp
108                             -       .endif
```

```
                                        tst     d0
                                        beq     noexit          ; IF (Keyboard Input Available) THEN
                                        Bconin  CON
                                *       move.w  #CON,-(sp)
                                *       Bios 2,4
                                *       move.w  #$2,-(sp)
                                *       trap    #13
                                *       .if $4 <= 8
                                *       addq    #$4,sp
                                *       .else
                                -       add.w   #$4,sp
                                -       .endif
                                        cmp.b   #'C'-64,d0
                                        beq     exit            ; CTRL-C ==> EXIT
                                noexit:
                                        bra     waveip
                                exit:
                                ;
                                ;       System Tear-Down
                                ;
                                        bclr.b  #0,iera
                                        bclr.b  #0,imra         ; Disable Hblank
                                        move.l  oldikbd,ikbdvec ; Restore System IKBD/MIDI Interrupt
                                        move.l  oldvbl,vblvec   ; Restore System VBlank Interrupt

                                        Gettime
                                *       Xbios   $17,2
                                *       move.w  #$17,-(sp)
                                *       trap    #14
                                *       .if $2 <= 8
                                *       addq    #$2,sp
                                *       .else
                                -       add.w   #$2,sp
                                -       .endif
                                        move.l  d0,vbltemp      ; Get IKBD Date/Time
                                        Tsettime d0
                                *       move    d0,-(sp)
                                *       Gemdos  $2d,4
                                *       move.w  #$2d,-(sp)
                                *       trap    #1
                                *       .if $4 <= 8
                                *       addq    #$4,sp
                                *       .else
                                -       add.w   #$4,sp
                                -       .endif
                                        Tsetdate vbltemp        ; Set GEMDOS Time and Date
                                *       move    vbltemp,-(sp)
                                *       Gemdos  $2b,4
                                *       move.w  #$2b,-(sp)
                                *       trap    #1
                                *       .if $4 <= 8
                                *       addq    #$4,sp
                                *       .else
                                -       add.w   #$4,sp
                                -       .endif

                                        lea     oldpal,a0
                                        lea     palette,a1
                                        move    #15,d0
                                .unplp: move.w  (a0)+,(a1)+
                                        dbra    d0,.unplp       ; restore old color palette

                                abort:  User                    ; return to user mode
                                *       Gemdos  $20,6
                                *       move.w  #$20,-(sp)
                                *       trap    #1
                                *       .if $6 <= 8
                                *       addq    #$6,sp
                                *       .else
                                -       add.w   #$6,sp
                                -       .endif
                                        Pterm0                  ; return to GEMDOS
                                *       clr.w   -(sp)
                                *       trap    #1
                                *       illegal

                                ;
                                ;       VBL     Vertical-Blank Interrupt Server
                                ;
                                vbl:
                                        movem.l d0-d1/a0-a2,-(sp)

                                        lea     video,a0        ; a0 = Display list (scroll,basel
                                        lea     xoffset,a1      ; a1 = Xoffset list
                                        lea     baseaddr,a2     ; a2 = Base address list
                                        move    #9,d1
                                .reglp:                         ; FOR (10 scrolling regions) DO
                                        move    (a1),d0         ; d0 = current Xoffset
                                        btst.l  #0,d1
                                        bne     .odd
                                        addq    #1,d0           ; EVEN --> Increment
```

```
000001FC  B07C00A0              cmp     #160,d0
00000200  6D00xxxx              blt     .join
00000204  7000                  moveq   #0,d0           ; Wrap-up
00000206  6000xxxx              bra     .join
0000020A  5340          .odd:   subq    #1,d0           ; ODD --> Decrement
0000020C  6C00xxxx              bge     .join
00000210  303C009F              move    #159,d0         ; Wrap-down
00000214  3280          .join:  move    d0,(a1)         ; New Xoffset
00000216  E240                  asr     #1,d0
00000218  C08C0000FFF0          and.l   #$0fff8,d0      ; d0 = byte offset within line
0000021E  D09A                  add.l   (a2)+,d0        ; d0 = Regions video base
00000220  2080                  move.l  d0,(a0)
00000222  3019                  move    (a1)+,d0
00000224  C07C000F              and     #$0f,d0         ; d0 = Regions horizontal scroll count
00000228  1080                  move.b  d0,(a0)
0000022A  5888                  addq.l  #4,a0
0000022C  51C9FFC2              dbra    d1,.reglp

00000230  41F9xxxxxxxx          lea     video,a0
00000236  1018                  move.b  (a0)+,d0
00000238  11C08265              move.b  d0,hscroll
0000023C  11D08205              move.b  (a0)+,vcounthi
00000240  11D08207              move.b  (a0)+,vcountmid
00000244  11D08209              move.b  (a0)+,vcountlo  ; Initialize first region

00000248  323C0050              move    #80,d1          ; Double normal ST line width
0000024C  4A00                  tst.b   d0
0000024E  6700xxxx              beq     .zero           ; IF (non-zero scroll count) Reduce line width
00000252  5941                  subq    #4,d1
00000254  11C1820F      .zero:  move.b  d1,linewid

00000258  2018                  move.l  (a0)+,d0
0000025A  E190                  rol.l   #8,d0
0000025C  23C0xxxxxxxx          move.l  d0,videodata    ; Init next lines data
00000262  23C8xxxxxxxx          move.l  a0,videoptr     ; Init display list ptr

00000268  11FC0000FA10          move.b  #0,tbcr
0000026E  11FC0014FA21          move.b  #20,tbdr        ; Interrupt every twenty HBlanks
00000274  11FC0008FA10          move.b  #8,tbcr

0000027A  4CDF0703              movem.l (sp)+,d0-d1/a0-a2
0000027E  4EF9                  .dc.w   $4ef9
00000280  00000000      oldvbl: .dc.l   0               ; JMP (Old-Vblank)
00000284  4AFC                  illegal


                        ;
                        ;       IKBD    IKBD/MIDI Interrupt Server
                        ;
                        ikbd:
00000286  3F00                  move    d0,-(sp)

00000288  40C0                  move    sr,d0
0000028A  C07CF8FF              and     #$f8ff,d0
0000028E  807C0500              or      #$500,d0
00000292  46C0                  move    d0,sr           ; Set IPL down to 5

00000294  301F                  move    (sp)+,d0
00000296  4EF9                  .dc.w   $4ef9
                        oldikbd:
00000298  00000000              .dc.l   0               ; JMP (Old-IKBD)
0000029C  4AFC                  illegal


                        ;
                        ;       HBL     *ONE LINE* Horizontal-Blank Interrupt Server
                        ;
                        hbl:
0000029E  48E78080              movem.l d0/a0,-(sp)     ;                       (44+28=72)

000002A2  2039xxxxxxxx          move.l  videodata,d0    ; d0 = vcount/scroll    (28)
000002A8  41F88205              lea     vcounthi,a0     ; a0 = movep base       (8)
000002AC  11C08265              move.b  d0,hscroll      ; set HScroll           (12)
000002B0  01C88000              movep.l d0,(a0)         ; set VideoBase         (24)
                                                        ;                       (total = 136+ cycles)
000002B4  4A00                  tst.b   d0
000002B6  6700xxxx              beq     .zero           ; IF (non-zero scroll count) Reduce line width
000002BA  11FC004C820F          move.b  #76,linewid
000002C0  6000xxxx              bra     .join
000002C4  11FC0050820F  .zero:  move.b  #80,linewid
                        .join:
000002CA  2079xxxxxxxx          move.l  videoptr,a0
000002D0  2010                  move.l  (a0)+,d0
000002D2  E190                  rol.l   #8,d0
000002D4  23C0xxxxxxxx          move.l  d0,videodata    ; Init next regions data
000002DA  23C8xxxxxxxx          move.l  a0,videoptr

000002E0  4CDF0101              movem.l (sp)+,d0/a0
000002E4  08B80000FA0F          bclr.b  #0,isra         ; Clear In-Service bit
000002EA  4E73                  rte


                        ;
                        ;       DATA STORAGE
```

```
245                                     ;
246  000002EC                           .data
247                                     neofile:                        ; NEO filename search string
248  00000000  2A2E6E6F6F00            .dc.b   "*.neo",0
249
250                                     .even
251
252                                     ;
253                                     ;       RANDOM DATA STORAGE
254                                     ;
255  00000006                           .bss
256
257                                     oldpal:
258  00000000 =00000010                 .ds.l   16              ; Original color palette
259                                     handle:                         ; Active Handle
260  00000040 =00000001                 .ds.w   1
261
262                                     baseaddr:                       ; Image Base address for each strip
263  00000042 =0000000A                 .ds.l   10
264                                     xoffset:                        ; Pixel-offset for each strip
265  0000006A =0000000A                 .ds.w   10
266                                     video:                          ; HScroll and Video Base address for each strip
267  0000007E =0000000A                 .ds.l   10
268                                     videoptr:                       ; Display list ptr
269  000000A6 =00000001                 .ds.l   1
270                                     videodata:                      ; Next regions display info
271  000000AA =00000001                 .ds.l   1
272
273                                     neobuff:                        ; NEO-Image Buffer
274  000000AE =00007D88                 .ds.b   32128
275                                     bigbuff:                        ; Mega-Image Buffer
276  00007E2E =0000FA00                 .ds.b   2*32000
277
278                                     vbltemp:                        ; Vblank Temporary Storage
279  0001782E =00000001                 .ds.l   1
280
281  00017832 =00000100                 .ds.l   256             ; (stack body)
282                                     mystack:
283  00017C32 =00000001                 .ds.l   1               ; Local Stack Storage
284
285                                     .end
```

Symbol Table

```
.dublp 000000E2 t
.join 00000214 t
.join 000002CA t
linlp 000000DE t
.odd 000002BA t
.ploop 000000C2 t
.reglp 000001F0 t
.strlp 00000188 t
unplp 000001C2 t
.zero 00000254 t
.zero 000002C4 t
AUX 00000001 ea
BBASE 00000010 a
BLEN 0000001C a
BPSZ 00000100 ea
BSIZE 0000000A a
BSSSZ 0000001C ea
CMDLINE 00000080 a
CON 00000002 ea
CR 0000000D ea
CURS_BLINK 00000002 ea
CURS_GETRATE 00000005 ea
CURS_HIDE 00000000 ea
CURS_MODLINK 00000003 ea
CURS_SETRATE 00000004 ea
CURS_SHOW 00000001 ea
DATASZ 00000014 ea
DBASE 00000010 a
DLEN 00000014 a
DSIZE 00000006 a
DTA 00000020 a
ENVIR 0000002C a
FILE_ID 00000000 a
HEADSIZE 0000001C ea
HITPA 00000004 a
IKBD 00000004 ea
LF 0000000A ea
LOWTPA 00000000 a
MIDI 00000003 ea
MYDTA 00000028 ea
PARENT 00000024 a
PRT 00000000 ea
RAWCON 00000005 ea
SSIZE 0000009E a
TA0 00000009 ea
TBASE 00000008 a
TEXTSZ 0000000C ea
TLEN 0000000C a
TSIZE 00000002 a
XXX1 00000012 a
XXX2 00000016 a
XXX3 0000001A a
XXXX 00000028 a
_____md 0000049E ea
_autopath 000004CA ea
_bootdev 00000446 ea
_bufl 00000482 ea
_cmdload 00000482 ea
_drvbits 000004C2 ea
_dskbufp 000004C6 ea
_frclock 00000466 ea
_fverify 00000444 ea
_hz_200 0000048A ea
_membot 00000432 ea
_memtop 00000436 ea
_nflops 000004A6 ea
_prt_cnt 000004EE ea
_prtabt 000004F0 ea
_shell_p 000004F6 ea
_sysbase 000004F2 ea
_tlmr_ms 00000442 ea
_v_bas_ad 0000044E ea
_vbclock 00000462 ea
_vbl_list 000004CE ea
_vblqueue 000004S6 ea
abort 000001C8 t
aer FFFFFA03 ea
baseaddr 00009042 b
bigbuff 00087E2E b
cmdreg 00000080 ea
colorptr 0000045A ea
constate 000004A8 ea
conterm 00000484 ea
criticret 0000048A ea
datareg 00000086 ea
ddr FFFFFA05 ea
defshiftmd 0000044A ea
diskctl FFFF8604 ea
dmahl FFFF8609 ea
dmalo FFFF860D ea
dmamid FFFF860B ea
dtr 00000010 ea
end_os 000004FA ea
etv_critic 00000404 ea
etv_term 00000408 ea
etv_timer 00000400 ea
etv_xtra 0000040C ea
exec_os 000004FE ea
exit 00000172 t
fifo FFFF8606 ea
flock 0000043E ea
glasmp 00000008 ea
glbsmp 00000009 ea
glcsmp 0000000A ea
glcrnvlp 0000000C ea
glflenvlp 00000008 ea
glmixer 00000007 ea
glnoise 00000006 ea
glporta 0000000E ea
glportb 0000000F ea
glread FFFF8800 ea
glselect FFFF8800 ea
gltoneac 00000001 ea
gltoneaf 00000000 ea
gltonebc 00000003 ea
gltonebf 00000002 ea
gltonecc 00000005 ea
gltonecf 00000004 ea
glwrit.. FFFF8802 ea
gplp FFFFFA01 ea
gpo 00000048 ea
handle 00000040 b
hbl 0000029E t
hblvec 00000128 ea
hdv_boot 0000047A ea
hdv_bpb 00000472 ea
hdv_init 0000046A ea
hdv_mediach 0000047E ea
hdv_rw 00000476 ea
hscroll FFFF8265 ea
iera FFFFFA07 ea
ierb FFFFFA09 ea
ikbd 00000286 t
ikbdvec 00000118 ea
imra FFFFFA13 ea
imrb FFFFFA15 ea
ipra FFFFFA0B ea
iprb FFFFFA0D ea
isra FFFFFA0F ea
isrb FFFFFA11 ea
keybd FFFFFC02 ea
keyctl FFFFFC00 ea
linemid FFFF820F ea
memcntlr 00000424 ea
memconf FFFF8001 ea
memval2 0000043A ea
memvalid 00000420 ea
mfp FFFFFA00 ea
midi FFFFFC06 ea
midictl FFFFFC04 ea
mystack 00017C32 b
neobuff 000006AE b
neofile 00000000 d
noexit 00000170 t
nvbls 00000454 ea
oldikbd 00000298 t
oldpal 00000000 b
oldvbl 00000280 t
palette FFFF8240 ea
palmode 00000448 ea
phystop 0000042E ea
prv_aux 00000512 ea
prv_auxo 0000058E ea
prv_lst 0000050A ea
prv_lsto 00000586 ea
resvalid 00000426 ea
resvector 0000042A ea
rezmode FFFF8260 ea
rsr FFFFFA20 ea
sav_context 000004AE ea
save_row 000004AC ea
savptr 000004A2 ea
scr FFFFFA27 ea
scr_dump 00000502 ea
screenpt 0000045E ea
secreg 00000084 ea
seekrate 00000440 ea
sshiftmd 0000044C ea
start 00000000 t
strobe 00000020 ea
swv_vec 0000046E ea
syncmode FFFF820A ea
tacr FFFFFA19 ea
tadr FFFFFA1F ea
tbcr FFFFFA1B ea
tbdr FFFFFA21 ea
tcdcr FFFFFA1D ea
tcdr FFFFFA23 ea
tddr FFFFFA25 ea
themd 0000048E ea
trkreg 00000002 ea
trp14ret 00000486 ea
tsr FFFFFA2D ea
ucr FFFFFA29 ea
udr FFFFFA2F ea
vbasehi FFFF8201 ea
vbaselo FFFF820D ea
vbasemid FFFF8203 ea
vbl 000001D6 t
vblsem 00000452 ea
vbltemp 0001782E b
vblvec 00000070 ea
vcounthi FFFF8205 ea
vcountlo FFFF8209 ea
vcountmid FFFF8207 ea
video 0000007E b
videodata 000000AA b
videoptr 000000A6 b
vr FFFFFA17 ea
wavelp 0000014A t
xoffset 0000006A b
xrts 00000008 ea
```

```
                                ;
                                ;       NEOWALL.S   Horizontal and Vertical Scrolling Demo
                                ;
                                ;       Copyright 1988 ATARI CORP.
                                ;       Started 10/10/88 .. Rob Zdybel
                                ;
                                
                                        .text
                                        .include atari
                                        .list
                                
                                ;
                                ;       HARDWARE CONSTANTS
                                ;
FFFF820D                        vbaselo =       $ffff820d               ; Video Base Address (lo)
FFFF820F                        linewid =       $ffff820f               ; Width of a scan-line (Words, minus 1)
FFFF8265                        hscroll =       $ffff8265               ; Horizontal scroll count (0 .. 15)
                                
                                ;
                                ;       SYSTEM CONSTANTS
                                ;
00000070                        vblvect =       $70             ; System VBlank Vector
                                
FFFFFFCE                        movec   =       -50             ; LineA Mouse-Motion Vector offset
FFFFFDA6                        cur_x   =       -602            ; LineA Current mouse Xpos
FFFFFDA8                        cur_y   =       -600            ; LineA Current mouse Ypos
                                
                                ;
                                ;       LOCAL CONSTANTS
                                ;
                                
                                ;
                                ;       System Initialization
                                ;
                                start:
00000000 2A4F                           move.l  a7,a5
00000002 2E7Cxxxxxxxx                   move.l  #mystack,a7     ; Get Our Own Local Stack
00000008 2A6D0004                       move.l  4(a5),a5        ; a5 = basepage address
0000000C 202D000C                       move.l  TEXTSZ(a5),d0
00000010 D0AD0014                       add.l   DATASZ(a5),d0
00000014 D0AD001C                       add.l   BSSSZ(a5),d0
00000018 D0BC00000100                   add.l   #$100,d0        ; RAM req'd = text+bss+data+BasePageLength
0000001E 2800                           move.l  d0,d4           ; d4 = RAM req'd
                                        Mshrink a5,d0           ; Return Excess Storage
00000020 2F00                   6       move.l  d0,-(sp)
00000022 2F0D                   6       move.l  a5,-(sp)
00000024 4267                   6       clr.w   -(sp)
                                6       Gemdos $4a,12
00000026 3F3C004A               6       move.w  #$4a,-(sp)
0000002A 4E41                   6       trap    #1
                                6       .if $c <= 8
                                -       addq    #$c,sp
                                -       .else
0000002C DEFC000C               6       add.w   #$c,sp
                                6       .endif
                                
                                ;
                                ;       Other Initialization
                                ;
                                        Super                   ; enter supervisor mode
00000030 42A7                   9       clr.l   -(sp)
00000032 3F3C0020               6       move.w  #$20,-(sp)
00000036 4E41                   6       trap    #1
00000038 5C4F                   6       addq    #6,sp
0000003A 2F00                   6       move.l  d0,-(sp)        ; WARNING - Old SSP saved on stack.
                                
                                        Fgetdta
                                6       Gemdos $2f,2
0000003C 3F3C002F               6       move.w  #$2f,-(sp)
00000040 4E41                   6       trap    #1
                                6       .if $2 <= 8
00000042 544F                   6       addq    #$2,sp
                                6       .else
                                -       add.w   #$2,sp
                                -       .endif
00000044 2840                           move.l  d0,a4
00000046 D8FC001E                       adda    #30,a4          ; a4 = Filename ptr
0000004A 7800                           moveq   #0,d4           ; d4 = Loop Count
                                        Fsfirst #neofiles,#0
0000004C 3F3C0000               6       move.w  #$0,-(sp)
00000050 2F3Cxxxxxxxx           6       move.l  #neofiles,-(sp)
                                6       Gemdos $4e,8
00000056 3F3C004E               6       move.w  #$4e,-(sp)
0000005A 4E41                   6       trap    #1
                                6       .if $8 <= 8
0000005C 504F                   6       addq    #$8,sp
                                6       .else
                                -       add.w   #$8,sp
                                -       .endif
                                .neoloop:                       ; FOR (Nine NEO Files) DO
0000005E 4A40                           tst     d0
00000060 6B00xxxx                       bmi     abort           ; IF (No more NEO files) ABORT
```

```
                                        Fopen   a4,#0
00000064  3F3C0000              *       move.w  #$0,-(sp)
00000068  2F8C                  *       move.l  a4,-(sp)
                                *       Gemdos $3d,8
0000006A  3F3C003D              *       move.w  #$3d,-(sp)
0000006E  4E41                  *       trap    #1
                                *       .if $8 <= 8
00000070  504F                  *       addq    #$8,sp
                                *       .else
                                -       add.w   #$8,sp
                                -       .endif
00000072  4A40                          tst     d0
00000074  6B00xxxx                      bmi     abort           ; IF (Error opening a file) ABORT
00000078  41F9xxxxxxxx                  lea     handlist,a0
0000007E  31804000                      move    d0,(a0,d4)      ; Save the Handle
00000082  5444                          addq    #2,d4
00000084  B87C0010                      cmp     #16,d4
00000088  6E00xxxx                      bgt     .gotnine
                                        Fseek   #128,d0,#0      ; Skip NEO Header
0000008C  3F3C0000              *       move.w  #$0,-(sp)
00000090  3F00                  *       move.w  d0,-(sp)
00000092  2F3C00000080          *       move.l  #$80,-(sp)
                                *       Gemdos $42,10
00000098  3F3C0042              *       move.w  #$42,-(sp)
0000009C  4E41                  *       trap    #1
                                *       .if $a <= 8
                                -       addq    #$a,sp
                                -       .else
0000009E  DEFC000A              *       add.w   #$a,sp
                                *       .endif
000000A2  4A80                          tst.l   d0
000000A4  6B00xxxx                      bmi     abort           ; IF (File Seek Error) ABORT
                                        Fsnext
                                *       Gemdos $4f,2
000000A8  3F3C004F              *       move.w  #$4f,-(sp)
000000AC  4E41                  *       trap    #1
                                *       .if $2 <= 8
000000AE  544F                  *       addq    #$2,sp
                                *       .else
                                -       add.w   #$2,sp
                                -       .endif
000000B0  60AC                          bra     .neoloop
                                .gotnine:
                                        Fread   d0,#128,#bigbuff
000000B2  2F3Cxxxxxxxx          *       move.l  #bigbuff,-(sp)
000000B8  2F3C00000080          *       move.l  #$80,-(sp)
000000BE  3F00                  *       move.w  d0,-(sp)
                                *       Gemdos $3f,12
000000C0  3F3C003F              *       move.w  #$3f,-(sp)
000000C4  4E41                  *       trap    #1
                                *       .if $c <= 8
                                -       addq    #$c,sp
                                -       .else
000000C6  DEFC000C              *       add.w   #$c,sp
                                *       .endif
000000CA  4A80                          tst.l   d0
000000CC  6B00xxxx                      bmi     abort           ; IF (File Read Error) ABORT
000000D0  45F9xxxxxxxx                  lea     bigbuff+4,a2
000000D6  41F80248                      lea     palette,a0
000000DA  43F9xxxxxxxx                  lea     oldpal,a1
000000E0  303C000F                      move    #15,d0
000000E4  32D8                  .ploop: move.w  (a0)+,(a1)+     ; save old color palette
000000E6  30DA                          move.w  (a2)+,(a0)+     ; create new color palette
000000E8  51C8FFFA                      dbra    d0,.ploop
000000EC  23FCxxxxxxxxxxxxxxxx          move.l  #bigbuff,buffptr
000000F6  7E00                          moveq   #0,d7           ; d7 = Row Count
000000F8  49F9xxxxxxxx          .rowlp: lea     threebuf,a4     ; FOR (Three rows) DO
000000FE  4BF9xxxxxxxx                  lea     handlist,a5
00000104  DAC7                          adda    d7,a5
00000106  3C3C0002                      move    #2,d6           ; d5 = Column Count
                                .redlp: Fread   (a5)+,#32000,a4 ; FOR (3 Files) DO Read into temp buff
0000010A  2F8C                  *       move.l  a4,-(sp)
0000010C  2F3C00007D00          *       move.l  #$7d00,-(sp)
00000112  3F10                  *       move.w  (a5)+,-(sp)
                                *       Gemdos $3f,12
00000114  3F3C003F              *       move.w  #$3f,-(sp)
00000118  4E41                  *       trap    #1
                                *       .if $c <= 8
                                -       addq    #$c,sp
                                -       .else
0000011A  DEFC000C              *       add.w   #$c,sp
                                *       .endif
0000011E  4A80                          tst.l   d0
00000120  6B00xxxx                      bmi     abort           ; IF (File Read Error) ABORT
00000124  08FC7D00                      adda    #32000,a4
00000128  51CEFFE0                      dbra    d6,.redlp

0000012C  43F9xxxxxxxx                  lea     threebuf,a1
00000132  45F9xxxxxxxx                  lea     threebuf+32000,a2
00000138  47F9xxxxxxxx                  lea     threebuf+64000,a3
```

```
 97  0000013E  2079xxxxxxxx                move.l  buffptr,a0
 98  00000144  3C3C00C7                    move    #199,d6         ; d6 = Scan Line Count
 99  00000148  3A3C0027            .linlp: move    #39,d5          ; FOR (200 Lines) DO
100  0000014C  20D9                .t1:    move.l  (a1)+,(a0)+     ; Copy a line from screen0
101  0000014E  51C8FFFC                    dbra    d5,.t1
102  00000152  3A3C0027                    move    #39,d5
103  00000156  20DA                .t2:    move.l  (a2)+,(a0)+     ; Copy a line from screen1
104  00000158  51C8FFFC                    dbra    d5,.t2
105  0000015C  3A3C0027                    move    #39,d5
106  00000160  20D8                .t3:    move.l  (a3)+,(a0)+     ; Copy a line from screen2
107  00000162  51C8FFFC                    dbra    d5,.t3
108  00000166  51CEFFE0                    dbra    d6,.linlp
109  0000016A  23C8xxxxxxxx                move.l  a0,buffptr
110  00000170  5C47                        addq    #6,d7
111  00000172  0E7C000C                    cmp     #12,d7
112  00000176  6F00                        ble     .romlp
113
114  00000178  7810                        moveq   #16,d4
115  0000017A  49F9xxxxxxxx                lea     handlist,a4
116  00000180  3F344000            .close: move    (a4,d4),-(sp)   ; FOR (Nine files) DO Close all
                                           Gemdos  $3e,4           ; Fclose
     00000184  3F3C003E            0       move.w  #$3e,-(sp)
     00000188  4E41                0       trap    #1
                                   0       .if $4 <= 8
     0000018A  584F                0       addq    #$4,sp
                                   0       .else
                                   -       add.w   #$4,sp
117                                -       .endif
118  0000018C  4A40                        tst     d0
119  0000018E  6B00xxxx                    bmi     abort           ; IF (Error Closing a file) ABORT
120  00000192  5544                        subq    #2,d4
121  00000194  6AEA                        bpl     .close
122
123  00000196  4EB9xxxxxxxx                jsr     initmaus        ; Install our own mouse handler
124
125  0000019C  23F80070xxxxxxxx            move.l  vblvect,oldvbl
126  000001A4  21FCxxxxxxxx0000            move.l  #vbl,vblvect    ; Capture System VBlank Interrupt
127
128                                    ;
129                                    ;       Scrolling Demo loop
130                                    ;
131                                    wavelp:
                                           Bconstat CON            ; Keyboard Polling
     000001AC  3F3C0002            0       move.w  #CON,-(sp)
                                   0       Bios 1,4
     000001B0  3F3C0001            0       move.w  #$1,-(sp)
     000001B4  4E4D                0       trap    #13
                                   0       .if $4 <= 8
     000001B6  584F                0       addq    #$4,sp
                                   0       .else
                                   -       add.w   #$4,sp
132                                -       .endif
133  000001B8  4A40                        tst     d0
134  000001BA  6700xxxx                    beq     noexit          ; IF (Keyboard Input Available) THEN
                                           Bconin  CON
     000001BE  3F3C0002            0       move.w  #CON,-(sp)
                                   0       Bios 2,4
     000001C2  3F3C0002            0       move.w  #$2,-(sp)
     000001C6  4E4D                0       trap    #13
                                   0       .if $4 <= 8
     000001C8  584F                0       addq    #$4,sp
                                   0       .else
                                   -       add.w   #$4,sp
135                                -       .endif
136  000001CA  B03C0003                    cmp.b   #'C'-64,d0
137  000001CE  6700xxxx                    beq     exit            ; CTRL-C ==> EXIT
138                                    noexit:
139  000001D2  60D8                        bra     wavelp
140                                    exit:
141                                    ;
142                                    ;       System Tear-Down
143                                    ;
144  000001D4  21F9xxxxxxxx0000            move.l  oldvbl,vblvect  ; Restore System VBlank Interrupt
145
146  000001DC  4EB9xxxxxxxx                jsr     unmaus          ; Restore System mouse handler
147
148  000001E2  41F9xxxxxxxx                lea     oldpal,a0
149  000001E8  43F88240                    lea     palette,a1
150  000001EC  303C000F                    move    #15,d0
151  000001F0  32D8                .unplp: move.w  (a0)+,(a1)+
152  000001F2  51C8FFFC                    dbra    d0,.unplp       ; restore old color palette
153
                                       abort:  User                    ; return to user mode
                                   0       Gemdos  $20,6
     000001F6  3F3C0020            0       move.w  #$20,-(sp)
     000001FA  4E41                0       trap    #1
                                   0       .if $6 <= 8
     000001FC  5C4F                0       addq    #$6,sp
                                   0       .else
                                   -       add.w   #$6,sp
154                                -       .endif
```

```
                                        Pterm0                  ; return to GEMDOS
    000001FE  4267              *       clr.w   -(sp)
    00000200  4E41              *       trap    #1
155 00000202  4AFC              *       illegal
156
157                                 ;
158                                 ;       VBL     Vertical-Blank Interrupt Server
159                                 ;
160                                 vbl:
161 00000204  48E78888                  movem.l d0/a0,-(sp)
162
163 00000208  3039xxxxxxxx              move    xmouse,d0
164 0000020E  C07C000F                  and     #$0f,d0
165 00000212  11C08265                  move.b  d0,hscroll      ; Xpos MOD 16 = Scroll count
166 00000216  4A00                      tst.b   d0
167 00000218  6600xxxx                  bne     .non0           ; IF (Scrolling) THEN 4 word offset
168 0000021C  11FC00A0828F              move.b  #160,linewid
169 00000222  6000xxxx                  bra     .join
170 00000226  11FC009C828F          .non0:  move.b  #156,linewid
171                                 .join:
172 0000022C  41F9xxxxxxxx              lea     bigbuff,a0
173 00000232  3039xxxxxxxx              move    ymouse,d0
174 00000238  C0FC01E8                  mulu    #3*168,d0       ; Ypos * Linewid = Vertical offset
175 0000023C  D1C0                      adda.l  d0,a0
176 0000023E  3039xxxxxxxx              move    xmouse,d0
177 00000244  E240                      asr     #1,d0
178 00000246  C07CFFF8                  and     #$fff8,d0       ; 8*(Xpos DIV 16) = Line offset
179 0000024A  D0C0                      adda    d0,a0           ; a0 = Video Base Address
180 0000024C  23C8xxxxxxxx              move.l  a0,vbltemp
181 00000252  11F9xxxxxxxx0000          move.b  vbltemp+1,vcounthi
182 0000025A  11F9xxxxxxxx0000          move.b  vbltemp+2,vcountmid
183 00000262  11F9xxxxxxxx0000          move.b  vbltemp+3,vcountlo
184
185 0000026A  4CDF0101                  movem.l (sp)+,d0/a0
186 0000026E  4EF9                      .dc.w   $4ef9
187 00000270  00000000              oldvbl: .dc.l   0               ; JMP (Old-Vblank)
188 00000274  4AFC                      illegal
189
190
191                                 ;
192                                 ;       MOUSE HANDLING
193                                 ;
194
195                                 ;
196                                 ;       INITMAUS   Capture system mouse
197                                 ;
198                                 ;       Given:
199                                 ;               Control
200                                 ;
201                                 ;       Returns:
202                                 ;               With motion and button vectors captured
203                                 ;
204                                 ;       Register Usage:
205                                 ;               destroys d0-d3 and a0-a3
206                                 ;
207                                 ;       Externals:
208                                 ;               none
209                                 ;
210                                 initmaus:
211 00000276  A000                      .dc.w   $a000           ; Line-A Trap
212 00000278  33E8FDA6xxxxxxxx          move    cur_x(a0),xmouse
213 00000280  33E8FDA8xxxxxxxx          move    cur_y(a0),ymouse
214 00000288  23E8FFCExxxxxxxx          move.l  movec(a0),moldvec
215 00000290  217Cxxxxxxxx0000          move.l  #ourmaus,movec(a0)      ; Take over mouse motion
216 00000298  4E75                      rts
217
218                                 ;       Mouse Motion Interrupt
219                                 ;
220                                 ourmaus:
221 0000029A  33C0xxxxxxxx              move    d0,xmouse
222 000002A0  33C1xxxxxxxx              move    d1,ymouse       ; Save new mouse position
223 000002A6  4EF9                      .dc.w   $4ef9
224                                 moldvec:
225 000002A8  00000000                  .dc.l   0               ; JMP (Old motion vector)
226 000002AC  4AFC                      illegal
227                                 ;
228                                 ;       UNMAUS   Restore mouse to system
229                                 ;
230                                 ;       Given:
231                                 ;               Control
232                                 ;
233                                 ;       Returns:
234                                 ;               Mouse and button vectors restored to system
235                                 ;
236                                 ;       Register Usage:
237                                 ;               destroys d0-d3 and a0-a3
238                                 ;
239                                 ;       Externals:
240                                 ;               none
241                                 ;
242                                 unmaus:
```

```
00000ZAE  A000                    .dc.w   $a000          ; Line-A Trap
00000200  2179000002A8FFCE        move.l  moldvec,movec(a0)       ; Restore mouse motion
00000208  4E75                    rts


                                  ;
                                  ;       DATA STORAGE
                                  ;
0000020A                          .data
                                  neofiles:                       ; NEO filename search string
00000000  2A2E6E656F00            .dc.b   "*.neo",0

                                  .even


                                  ;
                                  ;       RANDOM DATA STORAGE
                                  ;
00000006                          .bss

                                  oldpal:
00000000 =00000010                .ds.l   16            ; Original color palette

                                  handlist:                       ; Array of Active Handles (9)
00000048 =00000009                .ds.w   9
                                  buffptr:                        ; Load ptr for bigbuff
00000052 =00000001                .ds.l   1
                                  bigbuff:                        ; Mega-Image Buffer
00000056 =00046500                .ds.b   9*32000
                                  threebuf:                       ; Temporary Triple-Image Buffer
00046556 =00017700                .ds.b   3*32000

                                  voltemp:                        ; Vblank Temporary Storage
0005DC56 =00000001                .ds.l   1

                                  xmouse:                         ; Latest mouse Xposn
0005DC5A =00000001                .ds.w   1
                                  ymouse:                         ; Latest mouse Yposn
0005DC5C =00000001                .ds.w   1

0005DC5E =00000100                .ds.l   256           ; (stack body)
                                  mystack:
0005E05E =00000001                .ds.l   1             ; Local Stack Storage

                                  .end
```

Symbol Table

```
.close 00000100 t
.gotnine 00000002 t
.join 0000022C t
.linlp 00000148 t
.neoloop 000000SE t
.non0 00000226 t
.ploop 000000E4 t
.redlp 0000010A t
.ronlp 000000F8 t
.t1 0000014C t
.t2 00000156 t
.t3 00000160 t
.wnplp 000001F0 t
AUX 00000001 ea
BBASE 00000018 a
BLEN 0000001C a
BPS2 00000100 ea
BSIZE 0000000A a
BSSSZ 0000001C ea
CHDLINE 00000080 a
CON 00000002 aa
CR 0000000D ea
CURS_BLINK 00000002 ea
CURS_GETRATE 00000005 ea
CURS_HIDE 00000000 ea
CURS_NOBLINK 00000003 ea
CURS_SETRATE 00000004 ea
CURS_SHOW 00000001 ea
DATASZ 00000014 ea
DBASE 00000010 a
DLEN 00000014 a
DSIZE 00000006 a
DTA 00000020 a
ENVIR 0000002C a
FILE_ID 00000000 a
HEADSIZE 0000001C ea
HITPA 00000004 a
IKBD 00000004 ea
LF 0000000A ea
LOWTPA 00000008 a
MIDI 00000003 ea
MYDTA 00000028 ea
PARENT 00000024 a
PRT 00000000 ea
RAWCON 00000005 ea
SSIZE 0000000E a
TAB 00000009 ea
TBASE 00000008 a
TEXTSZ 0000000C ea
TLEN 0000000C a
TSIZE 00000002 a
XXX1 00000012 a
XXX2 00000016 a
XXX3 0000001A a
XXXX 00000020 a
_____md 0000049E ea
_autopath 000004CA ea
_bootdev 00000446 ea
_bufl 00000452 ea
_cmdload 00000482 ea
_drvbits 000004C2 ea
_dskbufp 000004C6 ea
_frclock 00000466 ea
_fverify 00000444 ea
_hz_200 000004BA ea
_membot 00000432 ea
_memtop 00000436 ea
_nflops 000004A6 ea
_prt_cnt 000004EE ea
_prtabt 000004F8 ea
_shell_p 000004F6 ea
_sysbase 000004F2 ea
_timr_ms 00000442 ea
_v_bas_ad 0000044E ea
_vbclock 00000462 ea
_vbl_list 000004CE ea
_vblqueue 00000456 ea
abort 000001F6 t
aer FFFFFA03 ea
bigbuff 00000056 b
buffptr 00000052 b
cmdreg 00000088 ea
colorptr 0000045A ea
constate 000004A8 ea
conterm 00000484 ea
criticret 0000048A ea
cur_x FFFFFDA6 ea
cur_y FFFFFDA8 ea
datareg 00000086 ea
ddr FFFFFA05 ea
defshiftmd 0000044A ea
diskctl FFFF8604 ea
dmahi FFFF8609 ea
dmalo FFFF860D ea
dmamid FFFF8606 ea
dtr 00000018 ea
end_os 000004FA ea
etv_critic 00000404 ea
etv_term 00000408 ea
etv_timer 00000400 ea
etv_xtra 0000040C ea
exec_os 000004FE ea
exit 000001D4 t
fifo FFFF8606 ea
flock 000004JE ea
giamp 00000000 ea
gibamp 00000009 ea
gicamp 0000000A ea
gicrnvlp 0000000C ea
giflenvlp 0000000B ea
gimixer 00000007 ea
ginoise 00000006 ea
giporta 0000000E ea
giportb 0000000F ea
giread FFFF8800 ea
giselect FFFF8800 ea
gitoneac 00000001 ea
gitoneaf 00000200 ea
gitonebc 00000003 ea
gitonebf 00000002 ea
gitonecc 00000005 ea
gitonecf 00000004 ea
giwrite FFFF8802 ea
gpip FFFFFA01 ea
gpo 00000040 ea
handlist 00000040 b
hdv_boot 0000047A ea
hdv_bpb 00000472 ea
hdv_init 0000046A ea
hdv_mediach 0000047E ea
hdv_rw 00000476 ea
hscroll FFFF8265 ea
iera FFFFFA07 ea
ierb FFFFFA09 ea
imra FFFFFA13 ea
imrb FFFFFA15 ea
initmaus 00000276 t
ipra FFFFFA0B ea
iprb FFFFFA0D ea
isra FFFFFA0F ea
isrb FFFFFA11 ea
keybd FFFFFC02 ea
keyctl FFFFFC00 ea
linewid FFFF820F ea
memcntlr 00000424 ea
memconf FFFF8001 ea
memval2 0000043A ea
memvalid 00000420 ea
mfp FFFFFA00 ea
midi FFFFFC06 ea
midictl FFFFFC04 ea
moldvec 000002A0 t
movec FFFFFFCE ea
mystack 0005E05E b
neofiles 00000000 d
noexit 000001D2 t
nvbls 00000454 ea
oldpal 00000000 b
oldvbl 00000270 t
ourmaus 0000029A t
palette FFFF8240 ea
palmode 00000448 ea
phystop 0000042E ea
prv_aux 00000512 ea
prv_auxo 0000050E ea
prv_ist 0000050A ea
prv_lsto 00000506 ea
resvalid 00000426 ea
resvector 0000042A ea
rezmode FFFF8260 ea
rsr FFFFFA2B ea
sav_context 000004AE ea
save_row 000004AC ea
savptr 000004A2 ea
scr FFFFFA27 ea
scr_dump 00000502 ea
screenpt 0000045E ea
secreg 00000084 ea
seekrate 0000044B ea
sshiftmd 0000044C ea
start 00000000 t
strobe 00000020 ea
swv_vec 0000046E ea
syncmode FFFF820A ea
tacr FFFFFA19 ea
tadr FFFFFA1F ea
tbcr FFFFFA1B ea
tbdr FFFFFA21 ea
tcdcr FFFFFA1D ea
tcdr FFFFFA23 ea
tddr FFFFFA25 ea
thand 0000048E ea
threebuf 00046556 b
trkreg 00000082 ea
trpl4ret 00000486 ea
tsr FFFFFA2D ea
ucr FFFFFA29 ea
udr FFFFFA2F ea
unmaus 000002AE t
vbasehi FFFF8201 ea
vbaselo FFFF8200 ea
vbasemid FFFF8203 ea
vbl 00000204 t
vblsem 00000452 ea
vbitemp 0005DC56 b
vblvect 00000070 ea
vcounthi FFFF8205 ea
vcountlo FFFF8209 ea
vcountmid FFFF8207 ea
vr FFFFFA17 ea
wavelp 000001AC t
xmouse 0005DC5A b
xrts 00000088 ea
ymouse 0005DC5C b
```

STE Digitized Sound
Developer information

The Atari STE™ family of computers is equipped to reproduce digitized sound using DMA (direct memory access; that is, without using the 68000). This document provides the information required to understand and use this feature.

OVERVIEW

Sound is stored in memory as digitized samples. Each sample is a number, from -128 to +127, which represents displacement of the speaker from the "neutral" or middle position. During horizontal blanking (transparent to the processor) the DMA sound chip fetches samples from memory and provides them to a digital-to-analog converter (DAC) at one of several constant rates, programmable as (approximately) 50KHz (kilohertz), 25KHz, 12.5KHz, and 6.25KHz. This rate is called the sample frequency.

The output of the DAC is then filtered to a frequency equal to 40% of the sample frequency by a four-pole switched low-pass filter. This performs "anti-aliasing" of the sound data in a sample-frequency-sensitive way. The signal is further filtered by a two-pole fixed frequency (16kHz) low-pass filter and provided to a National LMC1992 Volume/Tone Controller. Finally, the output is available at an RCA-style output jack on the back of the computer. This can be fed into an amplifier, and then to speakers, headphones, or tape recorders.

There are two channels which behave as described above; they are intended to be used as the left and right channels of a stereo system when using the audio outputs of the machine. A monophonic mode is provided which will send the same sample data to each channel.

The stereo sound output is also mixed onto the standard ST audio output sent to the monitor's speaker. The ST's GI sound chip output can be mixed to the monitor and to both stereo output jacks as well.

DATA FORMAT

Each sample is stored as a signed eight-bit quantity, where -128 (80 hex) means full negative displacement of the speaker, and 127 (7F hex) means full positive displacement. In stereo mode, each word represents two samples: the upper byte is the sample for the left channel, and the lower byte is the sample for the right channel. In mono mode each byte is one sample. However, the samples are always fetched a word at a time, so only an even number of mono samples can be played.

A group of samples is called a "frame." A frame may be played once or can automatically be repeated forever (until stopped). A frame is described by its start and end addresses. The end address of a frame is actually the address of the first byte in memory *beyond* the frame; a frame starting at address 21100 which is 10 bytes long has an end address of 21110.

Before continuing, please familiarize yourself with the DMA sound chip register set:

REGISTER DESCRIPTIONS

```
FF8900 ---- ---- ---- --cc RW Sound DMA Control
     cc:
     00  Sound DMA disabled (reset state).
     01  Sound DMA enabled, disable at end of frame.
     11  Sound DMA enabled, repeat frame forever.

FF8902 ---- ---- 00xx xxxx RW Frame Base Address (high)
FF8904 ---- ---- xxxx xxxx RW Frame Base Address (middle)
FF8906 ---- ---- xxxx xxx0 RW Frame Base Address (low)

FF8908 ---- ---- 00xx xxxx RO Frame Address Counter (high)
FF890A ---- ---- xxxx xxxx RO Frame Address Counter (middle)
FF890C ---- ---- xxxx xxx0 RO Frame Address Counter (low)

FF890E ---- ---- 00xx xxxx RW Frame End Address (high)
FF8910 ---- ---- xxxx xxxx RW Frame End Address (middle)
FF8912 ---- ---- xxxx xxx0 RW Frame End Address (low)

FF8920 0000 0000 m000 00rr RW Sound Mode Control
     rr:
     00   6258 Hz sample rate (reset state)
     01  12517 Hz sample rate
     10  25033 Hz sample rate
     11  50066 Hz sample rate
     m:
     0    Stereo Mode (reset state)
     1    Mono Mode

FF8922 xxxx xxxx xxxx xxxx RW MICROWIRE™ Data register
FF8924 xxxx xxxx xxxx xxxx RW MICROWIRE™ Mask register
```

Note: a zero can be written to the DMA sound control register at any time to stop playback immediately.

The frame address registers occupy the low bytes of three consecutive words each. The high bytes of these words do not contain anything useful, and it is harmless to read or write them. The frame address counter register is read-only, and holds the address of the next sample word to be fetched.

PROGRAMMING CONSIDERATIONS

The simplest way to produce a sound is to assemble a frame in memory, write the start address of the frame into the Frame Start Address register, and the end address of the frame into the Frame End Address register, set the Mode register appropriately (set stereo or mono, and the sample frequency), and write a one into the Sound DMA Control register. The frame will play once, then stop.

To produce continuous sound, and link frames together, more elaborate techniques are required.

The DMA sound chip produces a signal called "DMA sound active" which is one when the chip is playing sounds, and zero when it's not. When a frame ends in the repeat mode (mode 3), there is a transition from "active" to "idle" and back again on this signal. The signal is presented as the external input to MFP Timer A. You can put Timer A into Event Count mode and use it to generate an interrupt, for example when a frame has played a given number of times. Because of the design of the MFP, the active edge for this signal must be the same as the input on GPIP I4, which is the interrupt line from the keyboard and MIDI interfaces. It is, and the Active Edge Register is already programmed for that, so you need not worry about that if you use Timer A to count frames.

The DMA Sound chip's mode 3 (repeat mode) ensures seamless linkage of frames, because the start and end registers are actually double-buffered. When you write to these registers, what you write really goes into a "holding area". The contents of the holding area go into the true registers at the end of the current frame. (Actually, they go in when the chip is idle, which means right away if the chip was idle to begin with.)

If you have two frames which you want played in succession, you can write the start and end addresses of the first frame into the chip, then set its control register to 3. The first frame will begin playing. You can then immediately write the start and end addresses of the second frame into the chip: they will be held in the holding area until the first frame finishes, then they'll be copied into the true registers and the second frame will play. The interrupt between frames will still happen, so you can tell when the first frame has finished. Then, for instance, you can write the start and end registers for the start of a *third* frame, knowing that it will begin as soon as the second frame has finished. You could even write new data into the first frame and write its start and end address into the chip; this kind of ping-pong effect is rather like double-buffering of a graphics display.

Here is an example of using Timer A in Event Count mode to play a controlled series of frames. Suppose you have three frames, A, B, and C, and you want to play frame A three times, then frame B five times, and finally frame C twice. The sequence of steps below will accomplish this. Numbered steps are carried out by your program; the bracketed descriptions are of things which are happening as a result.

1. Set Timer A to event count mode, and its counter to 2 (not 3).

2. Write Frame A's start & end addresses into the registers.

3. Write a 3 to the sound DMA control register. [Play begins.] Go do something else until interrupted.

   [At the end of the second repetition of Frame A, the timer's interrupt fires. At the same time, frame A begins its third repetition.]

4. Write Frame B's start and end addresses into the DMA sound chip. These values will be held until the third repetition of Frame A finishes.

5. Set Timer A's count register to 5, then go away until interrupted

   [When the current repetition finishes, the start & end registers are loaded from the holding area, and Frame B will begin playing. The end-of-frame signal will cause Timer A to count from 5 to 4. At the end of Frame B's fourth repetition, its fifth will start, the timer will count down from 1 to 0, and the interrupt will occur.]

6. Write frame C's start & end addresses into the registers, and program Timer A to count to 2. Go away until interrupted.

   (When the current repetition (B's fifth) finishes, the start & end registers are loaded from the holding area, and Frame C will begin playing. The end-of-frame signal causes Timer A to count down from 2 to 1. When Frame C finishes its first repetition, Timer A counts down from 1 to 0 and interrupts.)

7. Write a 1 to the DMA Sound Control Register to play the current frame, then stop. Disable Timer A and mask its interrupt. You're done.

As you can see, you program the timer to interrupt after one repetition *less* than the number of times you want a frame to play. That is so you can set up the next frame while the DMA sound chip is playing the last repetition of the current frame. This ensures seamless linkage of frames.

INTERRUPTS WITHOUT TIMER A

Besides going to the external input signal of Timer A, the DMA-sound-active signal, true high, is exclusive-ORed with the monochrome-detect signal, and together they form the GPIP I7 input to the M68901 MFP. The intent of this is to provide for interrupt-driven sound drivers without using up the last general-purpose timer in the MFP. It is a little trickier to use, however. For one thing, it causes the interrupt at the end of every frame, not after a specified number of frames. For another, the "interesting" edge on this signal depends on what kind of monitor you have.

On an ST, monochrome monitors ground the mono-detect signal, so when you read the bit in the MFP you get a zero. Color monitors do not ground it, so it reads as a one. When the DMA sound is idle (0), this is still the case. However, when the sound is active (1), the mono-detect signal is inverted by the XOR, so the bit in the MFP reads the opposite way. (The one place where the OS reads this bit is at VBLANK time, to see if you've changed monitors. The ROMs on any machine with DMA sound are appropriately modified, so you need not worry about this.)

If you want to use the mono-detect / DMA interrupt signal, you have to set up the active-edge register in the MFP to cause the interrupt at the right time. The interesting edge on the DMA signal is the falling edge, that is, from active to idle; this happens when a frame finishes. If you have a monochrome monitor, this edge is seen as a transition from 1 to 0 on MFP bit I7. However, with a color monitor, the edge will be seen as a transition from 0 to 1. Therefore, you have to program the MFP's active-edge register differently depending on which monitor you have. Make sure the DMA sound is idle (write a zero to the control register), then check MFP I7: if it's one, you have a color monitor, and you need to see the rising edge. If it's zero, you have a monochrome monitor and you need to see the falling edge.

The DMA sound active signal goes from "active" to "idle" when a frame finishes. If it was playing in mode 1, it stays "idle" and the control register reverts to zero. If it was playing in mode 3, the signal goes back to "active" as the next frame begins. In this case, the signal is actually in the "idle" state for a very short time, but the MFP catches it and causes the interrupt, so don't worry.

Additional Considerations

Regardless of how you manage your interrupts, there is more you should know: the signal goes from "active" to "idle" when the DMA sound chip has *fetched* the last sample in the frame. There is a four-word FIFO in the chip, however, so it will be eight sample-times (four in stereo mode) before the sound actually finishes. If you are using mode 1, you can use this time to set up the chip with the start and end addresses of the next frame, so it will start as soon as the current one ends. However, if the interrupt should be postponed for four or eight sample-times, you could miss your chance to start the sound seamlessly. Therefore, for seamless linkage, use the pre-loading technique described above.

MICROWIRE™ Interface

The MICROWIRE™ interface provided to talk to the National LMC1992 Computer Controlled Volume / Tone Control is a general purpose MICROWIRE™ interface to allow the future addition of other MICROWIRE™ devices. For this reason, the following description of its use will make no assumptions about the device being addressed.

The MICROWIRE™ bus is a three wire serial connection and protocol designed to allow multiple devices to be individually addressed by the controller. The length of the serial data stream depends on the destination device. In general, the stream consists of N bits of address, followed by zero or more don't care bits, followed by M bits of data. The hardware interface provided consists of two 16 bit read/write registers: one data register which contains the actual bit stream to be shifted out, and one mask register which indicates which bits are valid.

Let's consider a mythical device which requires two address bits and one data bit. For this device the total bit stream is three bits (minimum). Any three bits of the register pair may be used. However, since the most significant bit is shifted first, the command will be received by the device soonest if the three most significant bits are used. Let's assume: 01 is the device's address, D is the data to be written, and X's are don't cares. Then all of the following register combinations will provide the same information to the device.

```
1110 0000 0000 0000 Mask
01DX XXXX XXXX XXXX Data

0000 0000 0000 0111 Mask
XXXX XXXX XXXX X01D Data

0000 0001 1100 0000 Mask
XXXX XXX0 1DXX XXXX Data

0000 1100 0001 0000 Mask
XXXX 01XX XXXD XXXX Data

1100 0000 0000 0001 Mask
01XX XXXX XXXX XXXD Data
```

As you can see, the address bits must be contiguous, and so must the data bits, but they don't have to be contiguous with each other.

The mask register must be written before the data register. Sending commences when the data register is written and takes approximately 16μsec. Subsequent writes to the data and mask registers are blocked until sending is complete. Reading the registers while sending is in progress will return a snapshot of the shift register shifting the data and mask out. This means that you know it is safe to send the next command when these registers (or either one) return to their original state. Note that the mask register does not need to be rewritten if it is already correct. That is, when sending a series of commands the mask register only needs to be written once.

Volume and Tone Control

The LMC1992 is used to provide volume and tone control. Before you go and find a data sheet for this part, be warned that we do not use all of its features. Commands for the features we do use are listed below.

Communication with this device is achieved using the MICROWIRE™ interface. See MICROWIRE INTERFACE the section for details. The device has a two bit address field, address = 10, and a nine bit data field. There is no way to reading the current settings.

Volume / Tone Controller Commands

Device address = 10

Data Field

```
011 DDD DDD Set Master Volume
    000 000 -80 dB
    010 100 -40 dB
    101 XXX  0 dB

101 XDD DDD Set Left Channel Volume
     00 000 -40 dB
     01 010 -20 dB
     10 1XX  0 dB

100 XDD DDD Set Right Channel Volume
     00 000 -40 dB
     01 010 -20 dB
     10 1XX  0 dB

010 XXD DDD Set Treble
      0 000 -12 dB
      0 110  0 dB (Flat)
      1 100 +12 dB

001 XXD DDD Set Bass
      0 000 -12 dB
      0 110  0 dB (Flat)
      1 100 +12 dB

000 XXX XDD Set Mix
          00 -12 dB
          01 Mix GI sound chip output
          10 Do not mix GI sound chip output
          11 reserved
```

Note: The volume controls attenuate in 2 dB steps. The tone controls attenuate in 2 dB steps at 50 Hz and 15 kHz (Note: These frequencies may change).

Using the MICROWIRE™ Interface and the Volume/Tone Control Chip

The MICROWIRE™ interface is not hard to use: once you get it right, you'll never have to figure it out again.

The easiest way to use it is to ignore the flexibility, and just use one form for all commands. Since the Volume/Tone chip is the only device, and it has a total of 11 bits of address and data, your mask should be $07ff. If you're picky, you can use $ffe0, because the high-order bits are shifted out first, but it adds conceptual complexity. With a mask of $07ff, the lower 9 bits of the data regsiter are used for the data, and the next higher two bits are for the address:

```
Mask:     %0000 0111 1111 1111
Data:     %xxxx x10d dddd dddd
```

Replace the d's with the command code and its data. For example, this combination sets the master volume to $14:

```
Mask:     %0000 0111 1111 1111
Data:     %xxxx x100 1101 0100
```

The other important concept you must understand is that the bits shift out of these registers as soon as you write the data, and it takes an appreciable time (16 µsec) to finish. You can't attempt another write until the first one is finished. If you read either register while it's being shifted out, you will see a "snapshot" of the data being shifted. You know the shifting is complete when the mask returns to its original value. (This theory is wrong if you use a mask which equals its original value sometime during the shifting, but $07ff never does.)

Assuming you write $07ff into the mask register ahead of time, the following routine can be used to write new data from the D0 register to the volume/tone control chip:

```
MWMASK    equ  $ffff8924
MWDATA    equ  $ffff8922

mwwrite:
     cmp.w     #$07ff,MWMASK  ; wait for prev to finish
     bne.s     mwwrite        ; loop until equal
     move.w    d0,MWDATA      ; write the data
     rts                      ; and return
```

The purpose of the loop at the beginning is to wait until a previous write completes. This loop is at the beginning of the routine, not the end, because waiting at the end would always force at 16 µsec delay, even if it's been longer than that since the last write.